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ABSTRACT

This collection of teaching activities was developed to provide teachers with guidance in presenting solar energy education to students of middle school age. The unit provides activities presenting learning opportunities involving: (1) passive solar collectors, (2) active solar collectors, (3) concentrating collectors, and (4) photovoltaic cell collectors. The guide is presented in the sequence: (1) introducing the unit (2 lessons): (2) characteristics of solar energy (3 lessons): (3) capturing solar energy (5-10 lessons): (4) complete solar systems (1-3 lessons): and (5) a summary. (RE)

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ENVIRONMENTAL EDUCATION

Occasional Paper # 2

Solar Energy

A Middle School Unit

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and

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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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February 1979

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SOLAR ENERGY UNIT

The following activities have been developed to provide information to aid teachers in presenting solar energy to students of middle school age. Most materials were developed at McGuffey Laboratory School, Miami University. Grades five through eight were used as the test group for all of the activities and some were tried with high school and college groups at Miami University. Revisions have taken place and all materials have been used successfully with various other student groups.

This unit will provide the teacher with activities to give the student an opportunity to learn about:

1. passive solar collectors,
2. active solar collectors (liquid and air types),
3. concentrating collectors, and
4. photovoltaic (silicon) cell collectors.

The Energy Picture

The U.S. energy consumption has been increasing by about 4% per year (14) for several decades and will probably continue at approximately this rate as long as sufficient energy is available. This 4% increase per year results in doubling the energy consumption every 15 years.

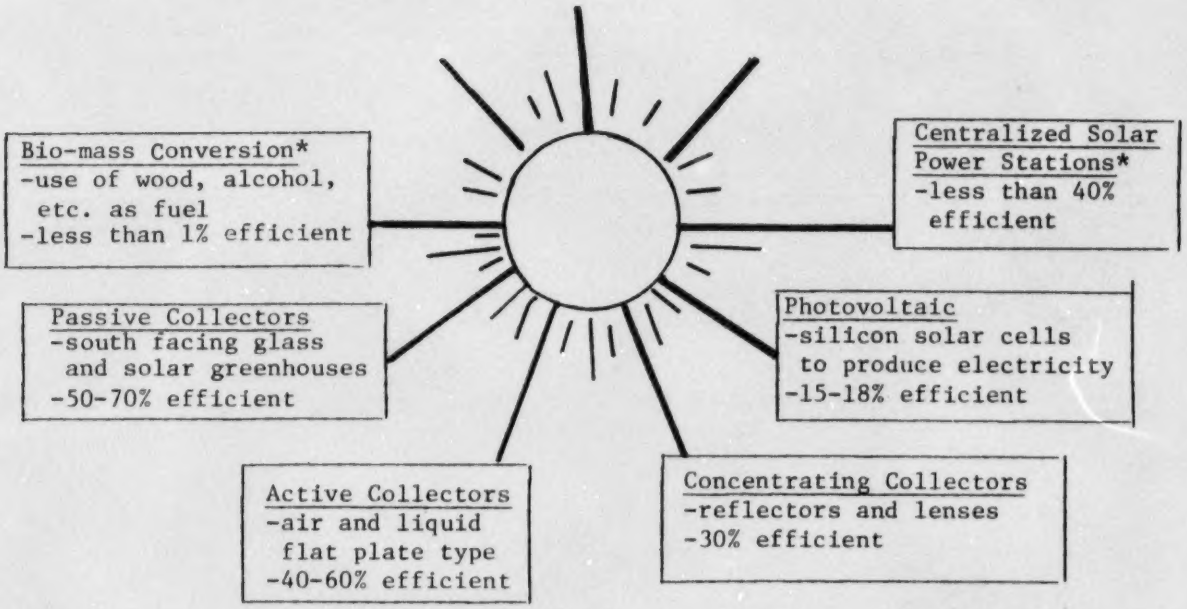
Each new double represents more energy consumed than the previous sum of energy consumed over the period of history being considered. This, if one barrel of oil is consumed in the first 15 years, then two barrels will be consumed in the next 15 years and four barrels of oil will be consumed in the next 15 years; 45 years have elapsed in our example and three barrels of oil were consumed in the first 30 years (1 + 2 barrels) but notice that one more barrel was consumed in the last 15 years than the sum of the first two periods. The next 15 years will result in eight barrels of oil consumed (previous sum is seven barrels 1 + 2 + 4) and the next period will result in the consumption of 16 barrels of oil (sum of previous periods is 15 barrels from 1 + 2 + 4 + 8).

This continued doubling produces compounding and always results in more consumption in the new period than the sum of all of the previous periods. This illustration teaches us that to make a supply of fuel, such as oil, last longer the rate of consumption must decrease, that is, we must reduce our rate of consumption and thus we must change our style of living toward less energy intensive (lower energy consumption) activities and occupations.

The energy picture might be improved by more efficient use of the energy that is now available (Fig. A). Passive, active, and concentrating collectors are the most efficient and will receive the most attention in the unit. Photovoltaic systems (silicon cells) show a lot of promise for the future and will receive some emphasis. Silicon cells may provide us with a decentralized electrical service at a reasonable cost by 1990.

Technology for centralized solar stations has not been developed to a very great extent at this time and will not provide the consumer with the self-sufficiency he/she is presently asking for and consequently will not be covered in this unit. The attached resources should be helpful should a teacher desire more information on this topic.

Bio-mass conversion, although low in efficient use of solar energy, does have some merit as a fuel because it is renewable. Also, there are a lot of areas where vegetation is growing and is very inexpensive. If it is available, then it makes sense to use it. Further discussion of this topic should be reserved for another unit on energy.



*Not covered in the unit

Fig. A

Ways of Collecting Sunlight and Their Approximate Efficiencies (% of sunlight converted to useable energy)

Good insulation is essential if solar systems are to function efficiently and economically. For this reason some emphasis will be given to selection and use of insulating materials.

Outline of the Unit

The following topics are covered in the activities recommended for the unit. Approximate teaching time is indicated.

I. Ways to Introduce the Unit (2 lessons)

II. Characteristics of Solar Energy (3 lessons)

- A. Advantages and disadvantages of solar energy
- B. Becoming familiar with the types of radiant energy (infrared, visible light, and ultraviolet) that must be trapped and changed to useable energy
- C. Black-pan experiment for demonstration of the "greenhouse" effect

III. Capturing Solar Energy (5-10 lessons or more if in-class time is allotted for project construction)

- A. The need for insulation
- B. Passive collectors (solar ovens)
- C. Active collectors (flatplate type)
- D. Concentrating collectors (lenses and reflectors)
- E. Photovoltaic (silicon cells to convert sunshine to electricity)

IV. Complete Solar Systems (1-3 lessons)

- A. Conventional heating systems
- B. Active solar systems
  - 1. liquid type
  - 2. air type
- C. Passive solar systems

V. Summary

WAYS TO INTRODUCE A SOLAR UNIT

1. One way to introduce this unit is by use of one of the many good films about energy problems. A film that provides general coverage of the energy situatior and also includes information about solar energy should be useful. The Department of Energy (formerly Energy Research and Development Administration (ERDA) will loan a good film for this purpose entitled Energy - A Family Album. (14) Another, perhaps even better, film but a much longer one is "Challenge of the Future" also available from the Department of Energy. (13)

Consult the resource list at the end of the unit for more information on how to secure a catalog for ordering energy related films. (21) Several films are listed with short annotations.

2. Another approach to preparing students for the solar energy unit (or any energy unit) is the use of reading assignments put together from newspaper clippings, magazine articles, and government publications, as well as science books or various library references. An excellent, free, government publication which is useful for this purpose, is Energy Conservation in the Home (see resources for ordering information). The first two sections, "Energy: The American Perspective" and "Energy Conservation" supply a great amount of information relevant to the energy situation.

(1) There are several questions that students might be expected to react to after completing the readings of the above type. These are: 1) write a short statement that summarizes the changes in the amount of energy consumption over the past 200 years; 2) develop a list showing the sequence of principle fuels (especially those used to heat homes) utilized in America over the past 200 years; 3) how much fuel is imported in America? When did we begin importing fuel?; 4) what part did OPEC (Organization of Petroleum Exporting Countries) play in the energy crises?; 5) how does U.S. energy consumption compare to that of the rest of the world?; 6) what (or who) are the major users of energy in America?

3. Harnessing The Sun produced by National Geographic Society is an excellent sound (cassette tape) filmstrip that can be obtained which is useful as introductory material. (2)

CHARACTERISTICS OF SOLAR ENERGY

It will be important for many students to have help in developing the concept of what solar energy is and the principles of how it is collected. The following activities should serve this purpose.

1. What energy do we capture?

Many students are familiar with the electromagnetic spectrum and the visible part of the spectrum. If this is not the case, then some additional time should be spent on this subject. Physical science books such as Modern Physical Science (2) are good sources for study in this area. Discuss the different types of waves that make up the electromagnetic spectrum (cosmic rays, x-rays, ultraviolet rays, visible rays, infrared rays, microwaves, and radiowaves.) For some, the visible spectrum might be better understood by a demonstration using a prism and light projector (Fig. 3) to project the rainbow of colors. This can also be accomplished by holding the prism in front of a sunny window and projecting the rainbow on the wall. Emphasize that it is ultraviolet, visible, and infrared waves that are converted to useable energy by common solar equipment.

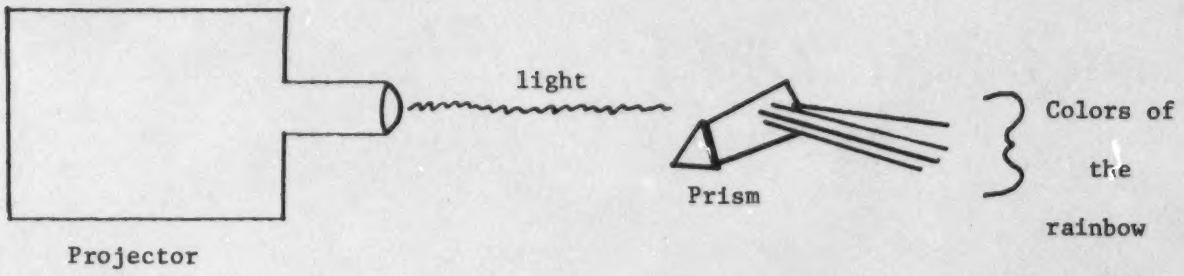


Fig. B.

2. The resource list at the end of the unit contains a film, The Solar Generation (19) which should be beneficial in helping students to understand the characteristics of solar energy and how it is used. Discuss the advantages and disadvantages of solar energy for heating homes. Students should begin preparing lists that will be expanded as this subject is explored over a week or two. Teachers should be sure to return to this discussion, as the solar science information becomes more complete.

3. Black Pan Experiment. (This exercise has worked well with primary students, teenagers, and adults).

The purpose of this experiment is to demonstrate a simple way to trap the sun's energy. Materials needed are a black bottom pan (any container that can be painted black or attach black paper or plastic to the bottom, even dissection pans with wax bottoms will work), a thermometer, and some plastic wrap or a sheet of clear plastic or glass. Add a couple of centimeters of water to the pan. Actually no water is needed, the air will heat up and show similar results but it is more dramatic with water. Place a small thermometer in the pan, and cover with the plastic wrap (Fig. C). Large thermometers can be used if the plastic wrap is sealed around them.

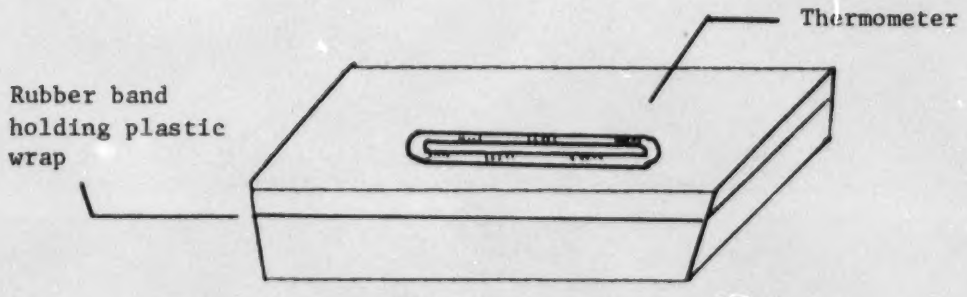


Fig. C.
Black Pan Experiment

The experiment can be done in a window if there is exposure to direct sunlight (a flood lamp can be used but this detracts from the value of the activity). If the experiment is done outside it is necessary to shield the pan from the wind (convection loss) and be sure to insulate the bottom of the pan (conduction loss) if it is placed on a cold surface. The teacher may choose to allow the students to encounter the convection and conduction loss problem without prior warning and then use this experience as a good inquiry problem for them to solve.

Students should record the initial temperature (this should be the same as the air temperature or a few degrees cooler) and continue recording the temperature every few minutes for at least 1/2 hour. Challenge them to get as high a temperature as possible within 30 - 60 minutes. Some students may invent ways to better insulate the container and thereby improve their results.

Post-lab discussions should center around the reasons for heat being trapped in this manner. The "greenhouse effect" should be explored thoroughly. Use any science materials available in your laboratory to help students determine that short waves (visible light) have been transmitted through the transparent cover (glazing) and absorbed by the black surface. The energy is thereby converted to long waves (infrared) which is not transmitted by the glazing. The increase in temperature of the water occurs in a similar manner as a closed car sitting in the bright sun. Most solar heating equipment (flatplate collectors) use this same principle for heating homes and commercial buildings.

CAPTURING SOLAR ENERGY

In this section several devices for capturing solar energy will be described. The teacher may want to select several of these and demonstrate how they are built and used. It would even be more appropriate if time was taken to build the collectors as student projects. Following a discussion of each collector, students could begin the project in class and finish it at home. Meanwhile other aspects of the unit could be continued in class. If some students become very involved their projects could be presented later in the year.

Some teachers find the project idea useful as a way of evaluating the unit and grade the project rather than give a test. Students can be grouped and thereby reduce expense of materials. The authors of this unit have organized solar field days in which students demonstrated their equipment for the school and community. Field days have been very successful and resulted in good publicity for the school.

1. The Need for Insulation

One of the first things a person discovers when they begin to work with solar collectors is the need for excellent insulation. Operating temperatures of solar equipment are much lower (30^{o} -- 150^{o} C) than conventional furnaces

(500° - 800°C). It is important to retain the heat that is trapped in solar equipment which requires convection, conduction, and radiation losses be kept to a minumum through the use of good insulation and good techniques.

The Cooperative Extension Service of The Ohio State University produces a pamphlet entitled House Insulation Types and Values, (8) (available free from a local extension office) which provides useful information about common insulating materials, Students would benefit from a discussion of "R" values which is a way of rating insulating materials on its resistance to heat passage. Most insulating products have the R-value printed on the package. A classroom display of some of these products would be valuable. Figure D contains the "R" values for some of the more common materials.

Material	Approximate "R" Value	
Loose Mineral Fiber rock, slag, glass	3.0-3.3	per inch
Loose Cellulouse (paper)	3.7	per inch
Loose Wood fiber	3.3	per inch
Loose Expanded Vermiculite	2.3	per inch
Blanket or Batt Mineral Fiber	3.0-3.7	per inch
Fiber Board	2.7	per inch
Polystyrene	3.6-6.3	per inch
Glass, one pane	.93	per inch
Glass, two panes	1.88	per inch
Glass, three panes	2.92	per inch

Fig. D

"R" Values of Some Common Insulating Materials

Note in Fig. D that there is considerable benefit from adding second and third layers of glass to the windows. If plastic sheets are used in place of glass the results are about the same. This information will be useful when students attempt to build collectors.

2. Passive Collector

Passive collectors are solar devices, usually for heating houses or greenhouses, that rely on the "greenhouse" effect to warm up an area without the use of blowers or other mechnical equipment to transfer or circulate the heat. Any south-facing window can serve as a passive collector. A complete passive system for a house will be discussed later. For this section a solar oven which can be constructed from cardboard, tape, and plastic can be used to demonstrate a passive solar device. The key features of this device are a black surface to absorb the sun and a transparent cover to keep the heat from escaping. Procedures for construction of the solar oven are as follows:

A. Select a cardboard box nearly cubical in shape with sides approximately 70-100cm on each side. A stronger oven can be built by constructing the sides of plywood.

B. Cut away one side of the box as shown in Fig. E.

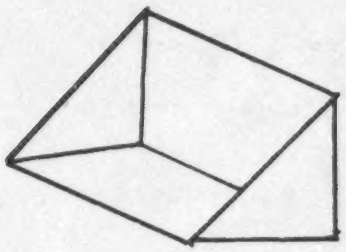


Fig. E.

C. The sides and bottom should be well insulated with 2-5cm of rigid styrofoam (or just add many thicknesses of cardboard). Be sure all cracks are well sealed. The inside surface must be given a black finish.

D. The angled front surface should be covered with at least 2 or 3 layers of transparent material (due to safety precautions plastic is preferred over glass). Spacers need to be attached around the edge before adding the extra layer of plastic to ensure an air space for insulation. A couple of fine strands of wire can be stretched across the surface if the plastic sags in the middle.

E. A door can be cut into the back of the box to provide access to the oven. Be sure it closes tight and keeps the heat in.

F. Flaps can be designed from cardboard, covered with aluminum foil, and taped in place as shown in Fig. F. These flaps can be angled to reflect additional sunlight into the oven.

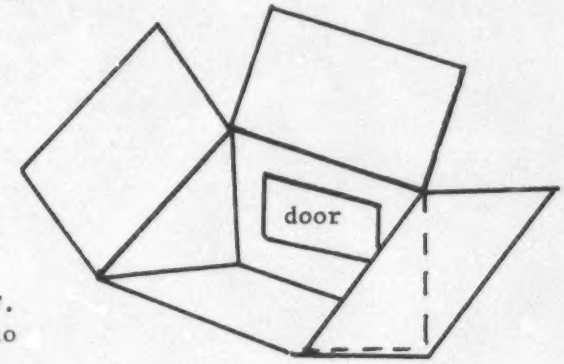


Fig. F.

G. Test the device and determine the kinds of food that can be prepared. Fifth graders have built ovens that reach temperatures of 150°c (300°F).

3. Constructing a Liquid-Type Flat Plate Collector (An Active Solar Collector)

A simple liquid type flat plate collector can be constructed from commmon materials found around the lab and home. Find a shallow (10-15cm) cardboard box (or cut off the bottom of a deeper box) about 60-100 centimeter long and locate some plastic tubing (flexible copper tubing is better but more expensive.) Pierce two holes in the box and arrange as shown in Fig. G. Paint the inside of the box, including the tubing, with flat black paint. Cover with transparent material (called glazing--clear plastic or glass) and you have a flat plate collector.

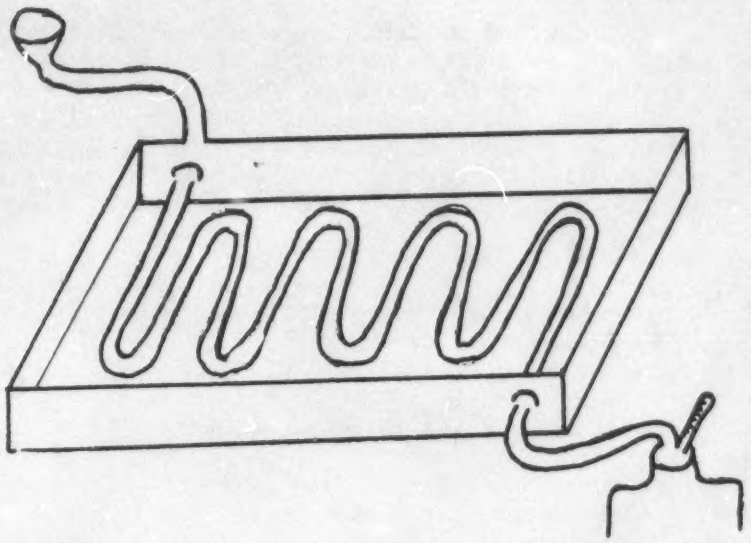


Fig. G.
Liquid Type
Flat Plate
Collector

Demonstrate this equipment to the class by facing the collector toward the sun and tilting it about 50-60° angle (best angle for collectors is latitude plus 15°). After a few minutes in the bright sun, pour air-temperature water in the funnel and measure the temperature increase when the water reaches the second jug. The efficiency of the collector can be improved by insulating (add more cardboard or styrofoam to the bottom and sides) the box and doubling the glazing. The latter can be done by adding a cardboard spacer and taping on a second layer of transparent material.

Encourage students to attempt the construction of their own collectors. More sophisiticated collectors can be built from wood and metal. Water can be circulated by adding a return tube and an inexpensive pump ($3.00-5.00 at discount stores) mounted on an electric drill. For about $3.00 Edmund Scientific sells a small pump that runs off D cells (batteries). (25)

4. Making an Air-Type Plate Collector (Another Active Collector)

The construction of this solar collector is much like that of the liquid type, except the box should have some cardboard baffles taped in as shown in Fig H. More baffles may be needed for a long box. Paint the inside

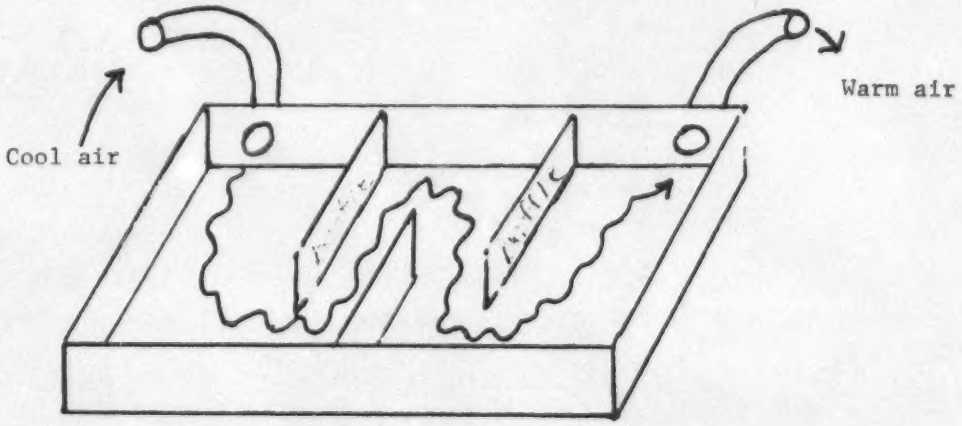


Fig. H. Air Type Flat Plate Collector

of the box black and add glazing as before. Remember the better the box is insulated, the more effective it will be. It is necessary to devise a method to move air through the system. Some teachers have used a tank type vacuum sweeper (on the blowing side), and some have devised ways of connecting a sock to a small fan. Also old hair dryers work well for circulating the air. A return tube could be devised to recirculate the same air. Again, encourage students to devise (invent) their own models.

5. Concentrating Collectors*

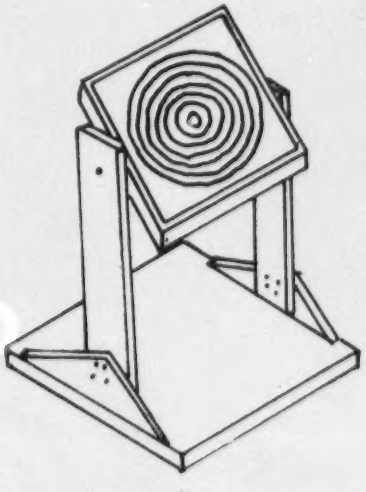
The principles of concentrating collectors should be investigated by the class. There are two common types, lens and reflector. The principles involved are commonly taught in science classes and are covered in physical and general science texts. Have students learn about spherical and parabolic reflectors and how light is reflected (concentrated) at a focus. Also investigate the action of light as it passes through a convex lens and comes to a focus. A projector light and large lens can be used to demonstrate the concentration of light. If a large convex lens (2-6 inch diameter) is available, this may be used to demonstrate how bright sun can be focused to ignite wood or dark colored paper (white will reflect the light).

A. Building a Lens Concentrating Collector

The most spectacular way to demonstrate the lens type solar collector is to use a Fresnel lens that is available from Edmund Scientific Company (25). A 12 inch Fresnel lens can be purchased for a few dollars and a book, Fun with Fresnel Lenses is included.(4) A free lens could be obtained by removing one from an old overhead projector.

The book explains how a Fresnel lens works (it works the same as a convex lens but it is cheaper because the material is a thin sheet of plastic). Instructions are included for making a support frame (Fig. I is a drawing of the way a seventh grader made the frame)

Fig. I



The value of concentrating collectors of this type is mainly as camp cookers and it really would not be necessary to construct both types that are discussed.

which can be constructed with scrap pieces of wood. A teacher could hold the lens by hand and demonstrate burning wood in bright sun but this is not recommended because temperatures at the focal point may reach 1200°C. Wood can be set ablaze in seconds. The lens should always be covered when transporting out of doors because a person can be burned quickly if the focal spot is in contact with skin or clothing.

B. Constructing a Cylindrical Parabolic Concentrator (Hotdog Cooker).

The shape of a parabola is more like a cone than a hemisphere. To make one of the simplest types of parabolic solar collectors (even suitable for primary grades) the hot dog cooker should be constructed as shown in Fig. K. The simplest construction method uses heavy poster board as described below.

a. Cut a piece of poster card the size desired for the reflecting surface (30x60 cm will work well).

b. Grasp at the ends and form an arc (Fig. J). Trace this arc on another piece of heavy cardboard and cut two identical pieces for sides (Fig. K.)

c. Cover the reflecting surface with heavy duty foil (some discount stores carry a heavy duty mending aluminum foil with an adhesive backing). Attach the sides to the edge of the cylindrical arc made by pushing on the ends of the reflector.

d. Determine the focal distance of the parabola and insert a coat hanger to serve as a skewer for hot dogs or colored marshmellows (white ones reflect light). Hot dogs, in bright sun, will cook in about twenty minutes or less. Edmund Scientific (25) sells an aluminum foil with a black side that works well for roasting weiners.

A black tube with corks can be substituted for the skewer if liquids are to be heated.

e. The focal distance (or line along which the skewer is to be placed) can be determined in several ways.

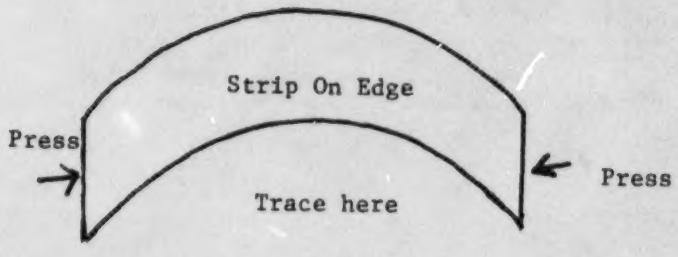
1. placing in the sun and observing where light rays cross on the sides.

2. placing your hand at various points until hottest place is found.

3. moving a pencil back and forth in front of the reflection surface until the image in the reflector turns upside down. The focal line is at the place where the pencil will appear to have an eraser on each end and is twice its normal length.

f. Cut out the side of a cardboard box to serve as a support base, as shown in Fig. K.

Note: Teachers should construct the cooker in advance so that they are familiar with the precautions necessary for the student to meet with success.



Hotdog Cooker

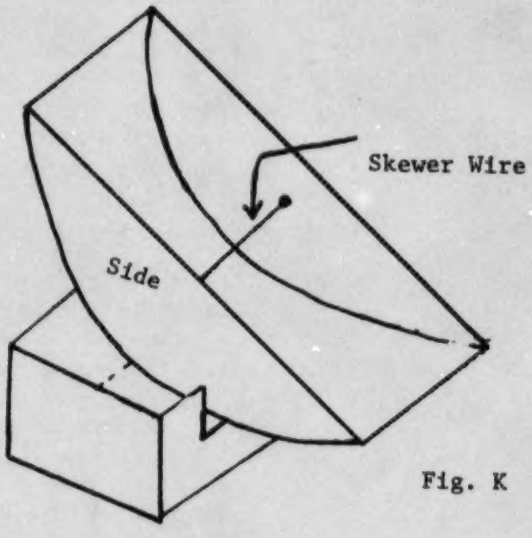


Fig. K

Extra challenge:

Advanced students can gain more experience in science from this activity by plotting their own parabolic curve. The following equation can be used to accurately determine the data for plotting the parabolic curve rather than using the tracing method outlined earlier.

$$y^2 = 4ax$$

$$y = \sqrt{4ax}$$

a= focal length--select whatever length you desire.

Determine about 15 points for y and plot these on graph paper or tag board. Select the size unit you prefer. The points have been determined for three different size collectors and are listed in Fig. L. If the teacher finds the students are unable to work from the formula, but graphing is within their capabilities, then use the points already calculated. Simply provide the lists of points given in Fig. L and ask the students to plot the parabola as indicated in the example. Additional lists of points for the parabolas could be calculated by the teacher if a wider choice of collector sizes is desired.

Points for collector A were plotted on the graph in Fig. L. The vertical axis is x and y is plotted on the horizontal axis. Additional points could be plotted then connected with a smooth curve and cut out to use as a pattern for

the ends of the collector. Other steps to constructing the collector are similar to those outlined in the first part of this section.

A) a=7		B) a=10		C) a=20	
$y^2=4ax$		$y^2=4ax$		$y^2=4ax$	
$y^2=4(7)x$		$y^2=4(10)x$		$y^2=4(20)x$	
$y^2=28x$		$y^2=40x$		$y^2=80x$	
$y=\sqrt{28x}$		$y=\sqrt{40x}$		$y=\sqrt{80x}$	
y	x	y	x	y	x
$\sqrt{28}=5.3$	1	$\sqrt{40}=6.3$	1	$\sqrt{80}=8.9$	1
$\sqrt{56}=7.5$	2	$\sqrt{80}=8.9$	2	$\sqrt{160}=12.6$	2
$\sqrt{84}=9.2$	3	$\sqrt{120}=10/9$	3	$\sqrt{240}=15.5$	3
$\sqrt{112}=10.6$	4	$\sqrt{160}=12.6$	4	$\sqrt{320}=17.9$	4
$\sqrt{140}=11.8$	5	$\sqrt{200}=14.1$	5	$\sqrt{400}=20.0$	5
$\sqrt{168}=13.0$	6	$\sqrt{240}=15.5$	6	$\sqrt{480}$ 21.9	6
$\sqrt{196}=14.0$	7	$\sqrt{280}=16.7$	7	$\sqrt{560}=23.7$	7
$\sqrt{224}=15.0$	8	$\sqrt{320}=17.9$	8	$\sqrt{640}=25.3$	8
$\sqrt{252}=15.9$	9	$\sqrt{360}=19.0$	9	$\sqrt{720}=26.8$	9
$\sqrt{280}=16.7$	10	$\sqrt{400}=20.0$	10	$\sqrt{800}=28.3$	10
$\sqrt{308}=17.5$	11	$\sqrt{440}=21.0$	11	$\sqrt{880}=28.7$	11
$\sqrt{336}=18.3$	12	$\sqrt{480}=21.9$	12	$\sqrt{960}=31.0$	12
$\sqrt{364}=19.1$	13	$\sqrt{520}=22.8$	13	$\sqrt{1040}=32.2$	13
$\sqrt{392}=19.8$	14	$\sqrt{560}=23.7$	14	$\sqrt{1120}=33.5$	14
$\sqrt{420}=20.5$	15	$\sqrt{600}=24.5$	15	$\sqrt{1200}=34.6$	15

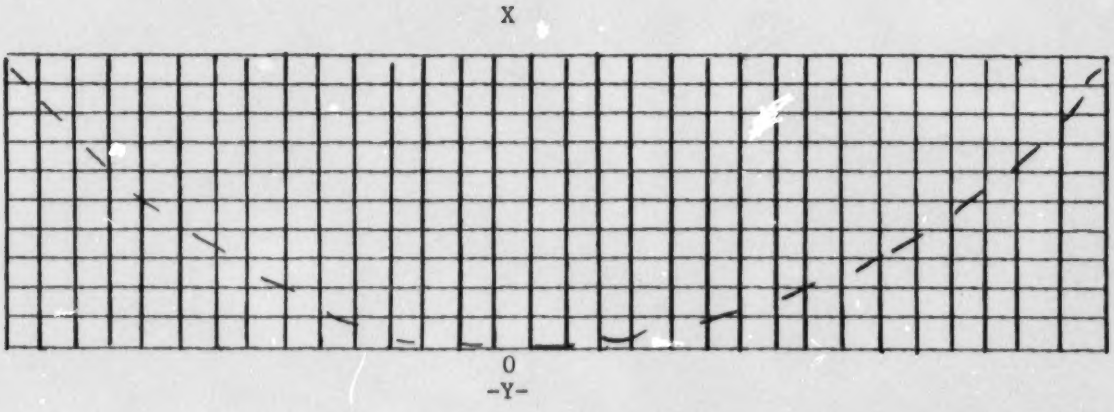


Fig. L

Information for Plotting Three Parabolas

6. Silicon Solar Cell Activities

One of the most promising future home energy sources is the photovoltaic or silicon cell. It provides a way of capturing sunlight and converting the solar energy directly to electricity. Silicon solar cells are one of the most efficient methods of achieving this direct conversion.

Silicon cells are made from very pure silicon (7 nines purity or 99.99999% pure silicon is required to make these cells). Thin slabs are cut from single crystals and then doped so that one side is negative (one more electron than silicon has for chemical bonding), achieved by doping with phosphorus, while the other side is positive (one less electron than Si. has for bonding), achieved by doping with boron. When light falls on the cell, electrons are boosted up into the conduction band (boosted in energy) where they are attracted to the junction created by the boundary where the two types of dopants meet in the silicon wafer. This junction creates a potential that attracts the electrons released by the light and thus causes current to flow.

The flow of current can be harnessed using special electrodes in contact with the two sides of the cell. This cell absorbs light mainly in the red and near infrared part of the spectrum and converts it to electricity at approximately 15 to 18% efficiency.

The major problem standing in the way of this solar application for routine use on homes is the cost of the cells which is about $12-$15/watt at the present time (1978). Predictions expect the cost to drop to about 50¢/watt by 1985-88 and to 15¢-20¢/watt by about 1990. If so, silicon cells as a source of energy for home heating should be able to compete with other energy systems.

The voltage generated by these cells is constant over a wide range of intensity of illumination. Only the current changes with changes in illumination. The power output by these cells can easily be determined by multiplying the voltage (0.42 volt) by the current measured during illumination.

Purchase a small silicon cell from a company such as Edmund Scientific (25) and obtain a small milliammeter. Arrange the equipment as shown in Fig. M. The silicon cell is taped to a shoe box and the milliammeter sits conveniently on top of the box. Most bright light sources will work and bright sunlight will give quite high readings. Students can turn on the light, take the current

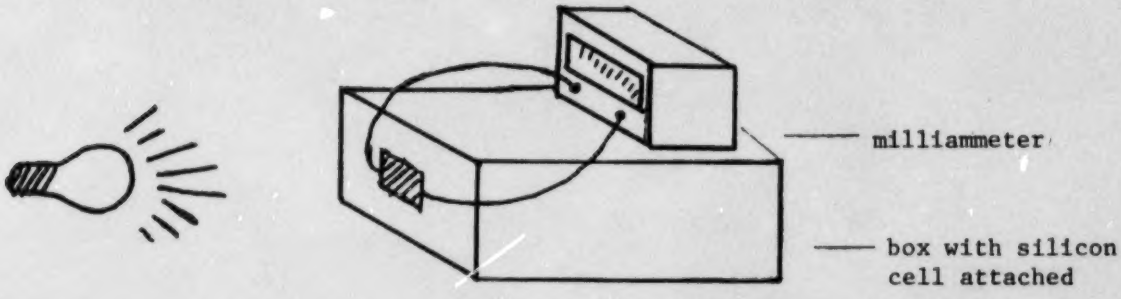


Fig. M Silicon Cell Demonstration

(milliamperes) readings and calculate the power output in milliwatts. The equation is milliamperes x volts (always 0.42) = milliwatts. Milliwatts can be converted to watts by dividing by one thousand.

Additional calculations can be made, if desired, but terms such as BTU or joules and building heat loss must be introduced. Students might enjoy trying to calculate the power needed to heat a model room similar to their own room. Assume the model room to have 14 square meters (150 ft^2) of floor area and that the insulation is average. The model room has one window and two oustide walls.

In the Cincinnati area on a -18°C (0°F) January day the model room could be expected to lose about 3,900,000 joule/hr (3700 BTU/hr) (from ASHRAE Handbook). One watt will provide 3600 joule/hr (3.41 BTU hr). How many watts will be needed to keep the model room warm for one hour? (1083 watts).

Very rough estimates can now be made for a typical house. It would take 6000 silicon cells (1 x 2 cm) to produce about 30 watts. The teacher can do more calculations on present and future silicon costs per watt for silicon cells as given earlier. This system may be a desirable choice for the school children who will be entering the housing market in the late 1980's and early 1990's.

How many silicon cells would it take to generate a kilowatt? At $12/watt determine the cost of a kilowatt. Discuss some applications of silicon cells at the present time. What are some future applications of these cells? What do the future applications depend on? Discuss.

COMPLETE SOLAR SYSTEMS

At some point during this unit it might be wise to discuss some solar heating systems and how they compare to a conventional furnace. So far

only the collector has been examined and no effort has been made to see how other components of the solar system might function. Students may not realize that some systems need a storage medium, especially if they are to provide any heat at night or during cloudy weather. Often solar equipment is connected to the existing furnace. For example the teacher might want to point out that the furnace blower is often used to circulate air through the solar collector and into the house.

The teacher may need to do some further reading on each system because the descriptions that follow are rather brief. The figures can be used to make overhead transparencies.

1. Conventional System

Figure N illustrates a conventional furnace which operates at very high temperatures (500-800°C). The flame is located in a fire box that is vented by a chimney. Cool air is pulled into a large compartment that partly surrounds the fire box. The air is warmed in this compartment then pushed out through a second duct. Sometimes air-type solar collectors can be hooked to the cool air duct of the conventional furnace. Pre-heated air is coming into the house and therefore the flame may not need to burn at all to maintain the house temperature.

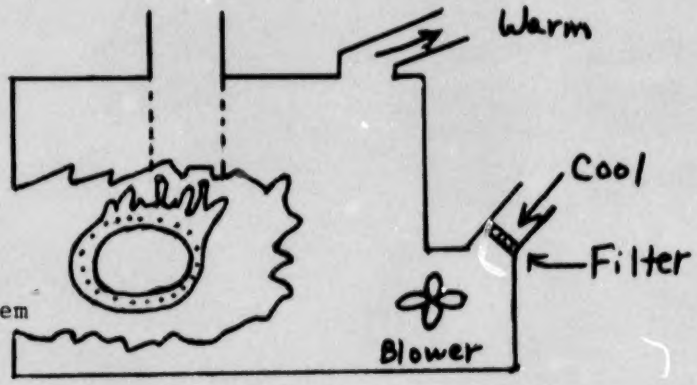


Fig N.
Conventional Heating System

2. Liquid-Type Solar Heating System (active)

The liquid solar home-heating system (Fig. O) requires an antifreeze solution to be circulated through a flatplate collector and back to a heat exchanger in the storage tank. The heat exchange in the storage tank is a coiled section of the pipe that allows heat to flow into the storage water. Hot water for domestic use can be drawn from the storage tank. Also the hot water can be circulated through a radiator (another heat exchanger) where it warms air that can be circulated through the house by a blower. The latter could be the air circulation system of a conventional furnace.

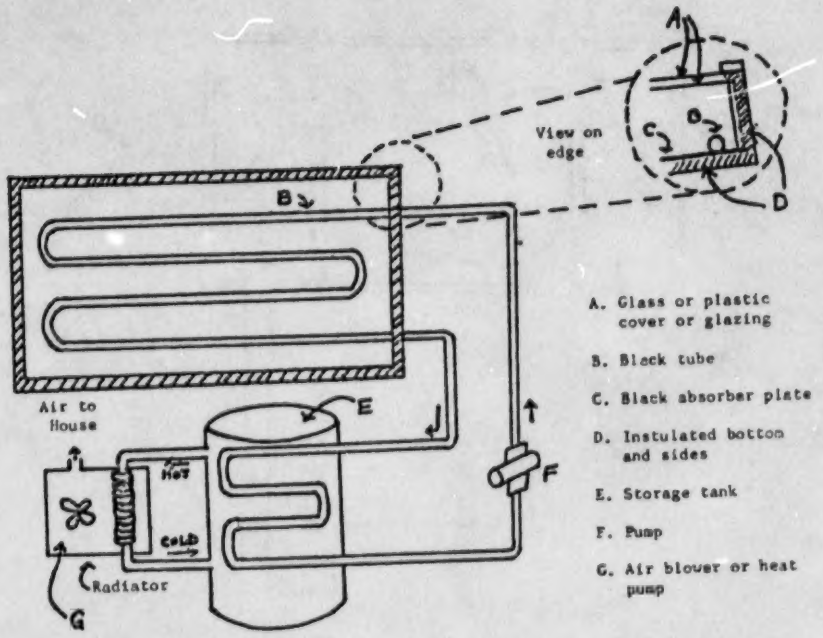


Fig. O Liquid-Type Solar Heating System

3. Air Type Solar Heating Systems (Active)

The baffled collector heats air on sunny days that can be taken directly into the house or if the house is warm enough the heated air can be diverted to rock storage. During nights or cloudy days cool air from the house can be pulled through the rocks where it is warmed and returned to the house.

House air is constantly routed automatically back through the collector or storage depending on where heat can be picked up. This type system often can be adapted to forced-air furnaces or heat pumps.

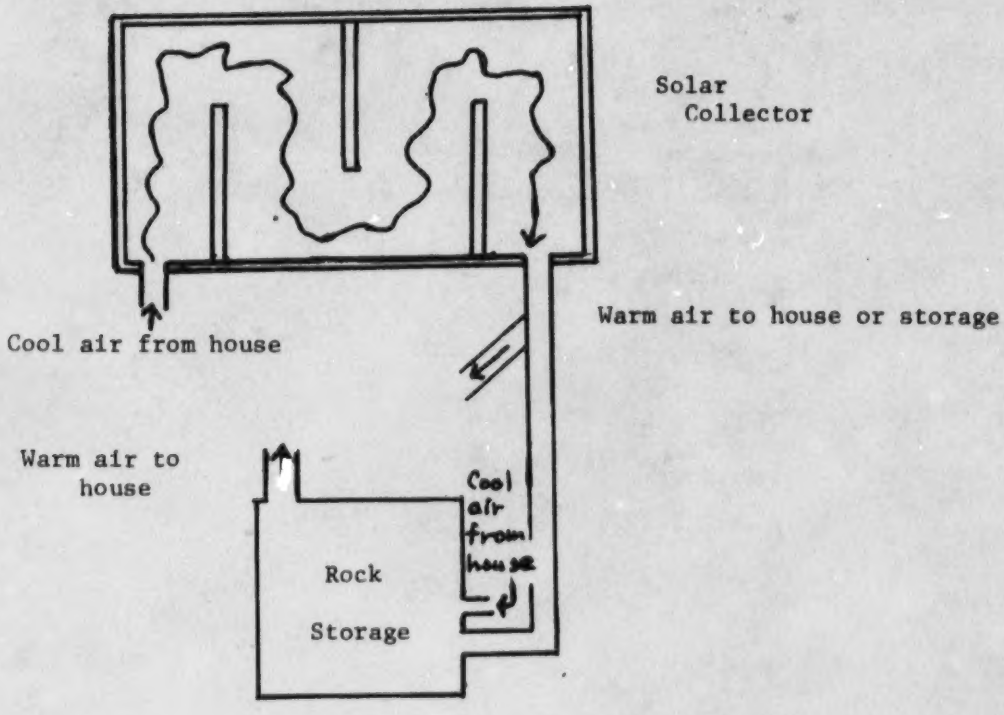


Fig P Air-Type Solar Heating System

4. Passive Solar System (also called Natural or Direct Solar Systems)

In the passive system (Fig. Q) there is a lot of glass wall exposed on the south side (all solar collectors need to be oriented toward the south) of the house to transmit a lot of sunlight.* Special heavy-constructed drapes or shutters can be pulled at night to insulate the window area. Some companies sell black fiber-glass tanks (sometimes drums are used when retrofitting) that can be installed behind the window to absorb the solar radiation. These act as absorbers. Because they are full of water, there is a great deal of mass that can be heated and often reradiates enough heat at night to assist in heating the house. A false wall can be constructed on the living area side of the tanks and vents can be installed to allow convection to circulate the air naturally while maintaining a pleasant appearance. Passive systems are defined as solar systems lacking the elaborate heat transfer devices (blowers, pumps, etc.) of active systems.

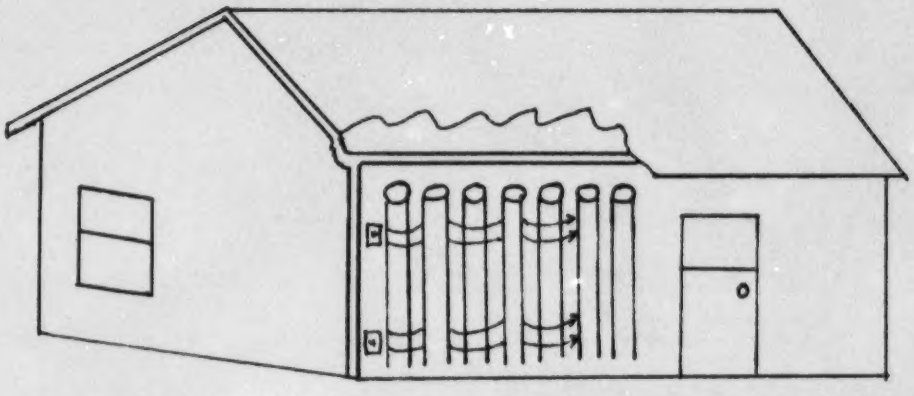


Fig Q Passive Solar Heating System

*some people construct a lean-to affair on the south side of the house and cover it with plastic

Summary

The focus of this unit was toward development of an awareness of how solar energy can be captured and utilized for heating homes. Most of the activities were directed to the construction of models of several of the more common solar collectors used for home heating and domestic hot water. After completion of the projects, students will be familiar with some of the most common solar equipment being used in Ohio.

There are several areas of study that did not receive adequate attention in this unit and probably should be considered for future instruction. Methods of storing solar energy was given only slight attention. Virtually no time was spent on the various kinds of controls that are needed to make solar systems completely automatic. There are economic and policital considerations with respect to solar energy that could be explored. Any solar installation probably needs a back-up heat source and students should study the economics of this problem. Some of these topics logically fit in the realm of industrial arts and social studies and the science teacher might seek the cooperation of other teachers in covering some of them.

RESOURCES

Books, Pamphlets, Articles:

1. ERDA, Energy Conservation in the Home, U.S. Department of Energy, October, 1977.

A very complete book (over 200 pages) of excellent activities for teaching energy conservation. Good background information about the energy problem. Prepared for home economics teachers but suitable for science and social studies.

2. Tracy, G.R., Troop, H.E., Friedl, A.E., Modern Physical Science, Holt, Rinehart and Winston, Inc., 1974.

A helpful reference for students trying to deal with such concepts as greenhouse effect, electromagnetic spectrum and the focusing of light from lenses or reflecting surfaces. Other physical science texts are equally useful.

3. Cantrell, Joseph and Mason, Jack, A Solar Energy Science Unit, unpublished monograph, 1977.

A complete unit of activities and projects which were developed for the eighth grade. A few copies are still available from the authors.

4. Edmund Scientific, Fun with Fresnel Lenses, Edmund Scientific Co., 1971.

Complete instructions for building projects utilizing the Fresnel lens.

5. Rankins, W.H. and Wilson, D.A., Practical Sun Power, Lorin House, 1974.

This booklet contains detailed plans for constructing several types of solar collectors.

6. Halacy, D.S., Jr. Solar Science Projects for a Cleaner Environment Scholastic Book Services, New York 1974.

As the title would indicate this is another source of plans for making solar devices. The reflector and thermo-siphon hot water heater are especially good.

7. ASHRAE Handbook. American Society of Heating, and Refrigeration, and Air Conditioning Engineering Handbook. Published periodically by the Society.

This is a handbook of data on heating, refrigeration and air conditioning for professional engineers for construction and maintenance of these stystem for offices, industry and homes. There data on calculating heat loss, insulation values and solar energy

data. This is useful for advanced students and for design problems and as a source of data for planning by teachers and advanced students. It is expensive.

8. Cooperative Extension Service, House Insulation Types and Values, Pamphlet L-255 by Cooperative Extension Service, The Ohio State University, Columbus, Ohio.

   The pamphlet explains what the term "R" value means and gives the "R" value of many insulating materials. It can be obtained free from local county cooperative extension offices.

9. HUD, In the Bank or Up The Chimney, ABT Associates, Inc., Cambridge, Mass., 1975.

   This booklet provides very complete information on why a house should be insulated, how to select insulation material, how to install them, and how to calculate your savings.

10. Miller, Jr., G.T., "Replenish the Earth", Wadsworth Publishing Co., Inc. (1972).

    This is a publication that discusses the problem of feeding the people of the world. A food pyramid is given that is useful to explain the problem of consumers of food high on the food chain.

11. Wade, C.G., "Contemporary Chemistry", Macmillan Publishing Co., Inc., New York, N.Y. (1976) pg. 54.

    This is a good book for an overall view of the energy and environment problems. Alternate sources of energy are discussed and many good sources are given for additional reading.

FILMS: (See ordering information below)

12. "Energy" The American Experience", available from DOE (ERDA) catalog number 507.

    Excellent introductory film that traces American power sources chronologically from about 1700 to the present. About 30 minutes.

13. "Challenge of the Future", DOE number 508.

    A good discussion of the energy problems, the conservation practices, and the research and development needed to meet the energy challenge of the future. About 30 minutes.

14. "Energy" A Family Album, DOE number 518.

    A brief survey of the history of American energy, conservation of energy, and alternate energy sources. About 8 minutes.

15. "Transportation the Way Ahead", DOE number 521.

    Very short film that emphasizes the high use of energy by our transportation systems. Discusses research on gas turbine cars, electric cars, and alternate fuels such as synthetic gases (coal, methanol) and metallic hydrides.

16. "Geothermal - Nature's Boiler", DOE number 519.

    A short discussion of the possible contribution that can be made by using volcanic heat as an alternate energy source.

17. "Look to the Sun", DOE number 513.

    A short but excellent, animated explanation of how a flat plate collector works to provide heat for a home.

18. "Sun Power for Farms", DOE number 512

    A short film that demonstrates ways that solar energy science is utilized on farms.

19. "The Solar Generation", DOE number 510.

    An excellent 15 minute film which reviews the history of solar energy development, discusses the pros and cons of solar energy and shows several solar devices (including solar homes) in operation.

FILMSTRIP:

20. "Harnessing the Sun". Published by National Geographic and available through educational supply houses.

Ordering Information

21. Order Energy Films Catalog from: ERDA Film Library, P. O. Box 62, Oak Ridge, Tennessee. 37830

22. Energy Conservation in the Home, Order on school stationery from U.S. Department of Energy, Technical Information Center, P. O. Box 62, Oak Ridge, Tennessee 37830.

23. Practical Sun Power, list price, $4.00. Obtain from: Lorien House, Publishers, P. O. Box 1112, Black Mountain, North Carolina.

24. In the Bank or Up the Chimney can be ordered from Superintendents of Documents, Government Printing Office, Washington, D.C. 20402. Price $1.70

About the authors.....

The OPEC oil embargo and the recent severe winters has caused me to become much more concerned with the world and the U.S. resources of energy. The realization that energy sources should be readily available, nonpolluting and nondepletable has led me to become interested and involved in direct use of solar energy as the most important source of energy for the future and an area that is within our reach today. My strong belief in education as one of the most important needs for changing the patterns of energy usage has led to my collaboration with Jack Mason. My background as a teacher and a researcher in Physics and Chemistry helps me to understand the problems of measurement and computation that are necessary to develop experiments and their explanations. This background also helps to explain techniques of capturing and utilizing solar energy. In addition this experience helps to develop explanations of energy conservation dealing with heat loss and the benefits to be gained from proper use of insulation.

.....Joseph S. Cantrell

Training in agriculture education, earth science and science education has helped me to understand some of the energy problems of our society. The energy crisis of recent years has awakened people, somewhat, and they have become more receptive to education in this area. During sixteen years as a science teacher I have often taught about solar energy and in the last two years due to more acceptance of solar energy as a viable alternative to fossil fuels and an opportunity to work with Joe Cantrell, a solar researcher, it has been possible to develop many energy activities for the classroom. Numerous investigations and projects related to energy conservation and solar science were devised, tested, refined, and results exhibited and published.

Students are anxious to participate in the study of solar science. Any teacher willing to make an effort in this area will be making a worthy contribution to society because a great deal of the burden for solving our energy problems lies with our young people.

.....Jack L. Mason

The authors wish to acknowledge and thank John Hug for his assistance in defining the overall purpose and objectives for this paper. He met with us to help organize the material and offered many good suggestions and ideas that were useful in the completion of the manuscript.

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OCCASIONAL PAPERS

This is the second in a series of papers designed to provide interested people with some current information about Environmental Education. The occasional paper format was chosen because it provides for rapid production and, therefore, timeliness. The short length of these papers will allow them to be distributed to different and specific audiences, thereby reducing the possibility of unused or wasted copies. Other topics now being considered for publication are:

An Explanation of Appropriate Technology

Using an Environmental Problem Solving Simulation in the Classroom

Descriptions of Environmental Education Experiences

Responsibilities of a School District Coordinator of Environmental Education

Suggestions for other topies will be welcome.

Authors for these papers will be Ohioans both in and out of the Ohio Department of Education and, therefore, the views expressed are those of the authors. The Ohio Department of Education only wishes to provide educators some food for thought by reproducing them for you.